APPENDIX A

CONSTRUCTION RECOMMENDATIONS

APPENDIX A

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TABLE OF CONTENTS

Page

APPENDIX A

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A.1 GROUNDWATER

A.1.1 Construction Dewatering

For structures that extend below groundwater, temporary construction dewatering may be necessary to control groundwater entering the excavation until the subsurface portion of the structure is completed. Temporary construction dewatering techniques include the use of sumps and ditches within the excavation, and/or large-diameter dewatering wells or vacuum-extraction well points outside (and sometimes within) the excavation. For deeper structures, dewatering of the advance outwash may be necessary to reduce uplift pressures at the base of excavations. In general, the use of these systems is short-term, depending on the period of construction.

Dewatering systems installed in soil and groundwater above the till and till-like soil could lead to ground settlement because of the resulting increase in effective stress acting on compressible soils. The area of influence of these dewatering systems on groundwater elevation and settlement depends on soil properties, dewatering system type, and duration of dewatering. Reducing groundwater pressures in the deeper advance outwash aquifer could lower the groundwater level in the upper soils. This possibility, which could also lead to settlement, depends on the interconnection of the shallow and deep groundwater zones, which is currently not known.

In lieu of construction dewatering, water-tight shoring could be used to control the inflow of groundwater into the excavation. Examples of water-tight shoring include interlocking sheet piles, slurry walls, and jet-grouting. Depending on soils, shoring installation technique, and methods used to seal openings, soldier piles and steel plate lagging might also be used for shoring where some inflow can be tolerated. If water-tight shoring is limited to the sidewalls of the excavation, construction dewatering may still be required to reduce groundwater inflow through the bottom of the excavation, and reduce uplift pressures that could cause basal instability.

If construction dewatering is used to control groundwater during excavation, monitoring of groundwater levels should be performed around the perimeter of the excavation to evaluate potential impacts to adjacent structures and facilities. Groundwater elevations and piezometric pressures should be monitored in the soil unit that is the focus of the dewatering effort, and in each of the compressible soil units encountered at the site. If drawdown of groundwater levels exceeds seasonal low groundwater elevations, ground settlements could occur, and mitigation measures should be implemented. Seasonal, low, groundwater elevations may be evaluated by long-term groundwater monitoring in the basin.

Dewatering induced drawdown could be limited by designing the dewatering systems to reduce the area of influence and drawdown in the compressible soils, and by recharging compressible soils outside the excavation to maintain water levels in these soils. Recharge systems could include injection wells and trenches.

An injection recharge system would involve the installation of wells in the compressible soils. Results of injection tests completed for this study indicate that injection of water may be slow and closely spaced wells would be required for the system to be effective. We do not recommend pressure injection of water into the soils because excess pressure could damage overlying or adjacent structures or facilities. We recommend maintaining a water level in gravity-flow injection wells at or slightly above ground surface.

Construction of infiltration trenches along the perimeter of excavations may be feasible, although the effectiveness of such a system is not known. If an infiltration trench is used, it should be installed in the compressible soils and care should be taken to isolate the water in the trench from soils. Leakage of water from the trench into the overlying fill deposits would reduce the efficiency of the system. Water levels in the trench should be maintained at ground surface.

A.1.2 Surface Water Management

Some of the groundwater elevation declines in the Greenwood area may be attributed to reduction in infiltration of stormwater that has occurred because of the creation of impervious surfaces, and routing of stormwater runoff to the storm drain system. Infiltration of stormwater may be an effective method of maintaining groundwater levels in the vicinity of new development. The Washington State Department of Ecology encourages the use of infiltration for stormwater management in their Western Washington Stormwater Manual (2001). It is unlikely that all stormwater could be infiltrated due to limited permeability of the peat and other fine-grained soils. Provisions to handle stormwater that is not infiltrated should be provided.

Several methods may be feasible to increase stormwater infiltration. Methods include (1) installing infiltration systems as part of the stormwater management plan for new developments, (2) retrofitting existing roof downspout systems to infiltrate rather than discharge to the storm drain, (3) improving the existing storm drain system to encourage exfiltration of water from the system into the surrounding soil, and (4) constructing infiltration structures on both City right-of-ways and private properties. For any type of infiltration system, both water quantity and water quality need to be considered.

Not all of the infiltration methods may be appropriate at a given location in the Greenwood basin. For any type of infiltration system, the feasibility of the system will be dependent on local soil and groundwater conditions. The impact of the infiltration system on existing structures and potential for localized flooding should be evaluated. Both water quantity and water quality of the stormwater runoff will need to be considered during design of infiltration systems.

A.1.2.1 Infiltration for New Developments

Larger developments are required by code to include stormwater management design in their development plans. These designs generally include collecting and routing stormwater runoff to detention structures to improve water quality prior to discharge to the storm drain system. In our opinion, alternative stormwater management systems could include infiltration galleries below impervious surfaces, such as parking areas and sidewalks, subsurface infiltration vaults, and pervious pavements. These systems need not be designed to infiltrate all of the water, just that necessary to maintain the groundwater elevation. Infiltration systems may not be practical in some instances because of water quality and long-term maintenance concerns.

A.1.2.2 Retrofitting Roof Downspouts

Currently, most roof runoff for new construction in the study area is collected and routed to the storm drain system. Infiltration of this water may be feasible because of the lesser concern of water quality issues associated with this type of runoff for most roof types. For some roof types, treatment of water prior to infiltration may be necessary. Infiltration may increase groundwater levels and cause local flooding of structures in low lying areas. Where these conditions occur, limiting infiltration or raising structures may be required.

A.1.2.3 Existing Storm Drain System

The current storm drain system contains some portions that have been perforated to encourage infiltration. It is our understanding that maintenance of the system has not occurred on a regular basis and the system may not be operating efficiently. Improvements to the drain system and regular maintenance could increase the exfiltration of water from the storm drain system and improve recharge.

A.1.2.4 Infiltration Structures

Seattle Public Utilities is currently working on several projects in Seattle to incorporate infiltration into stormwater management approaches at locations where this is feasible. These projects also attempt to control and improve stormwater runoff from streets and sidewalks by constructing infiltration structures that are designed to slow the movement of stormwater through the drain system, to reduce the peak discharge rate to local streams and improve water quality prior to discharge.

This approach to stormwater management can be evaluated in the Greenwood area for future public and private projects. Infiltration potential is highly dependent on local soil and groundwater conditions. Challenges for implementation of this approach include (1) finding suitable locations to build the structures, (2) retrofitting existing roads and sidewalks to direct stormwater runoff to the structures, (3) designing the system to meet required water quantity and quality criteria, (4) long-term maintenance, (5) initial construction cost, and (6) potential impacts to other structures and properties (flooding, for instance).

A.1.3 Foundation Drainage Systems

Construction of permanent drainage systems including foundation drains and footing drains has likely impacted groundwater levels in the Greenwood area. We recommend that future projects incorporate systems that reduce or eliminate the need for sumps and foundation drains, e.g., constructing water-tight, below-grade structure elements. Existing drainage systems should be evaluated for their impact on groundwater levels and modifications should be undertaken to reduce or eliminate the volume of water removed by these systems. Retrofitting of existing structures and foundation drainage systems may be necessary, although there may be financial, regulatory, and other challenges with implementing these retrofits.

A.2 STRUCTURE FOUNDATION SYSTEMS

Within the study area, we recommend that buildings not be founded on or above compressible soils. Small, non-critical, lightweight structures could be founded on or above the compressible soils provided that the structures can accommodate anticipated total and differential settlement that might occur at the site where they are located. Examples of lightweight structures for which these foundations might be appropriate, depending on City building codes, include, but may not be limited to, gazebos, sheds, and carports, and possibly residences founded over stiff clays and medium dense cohesionless soils.

We recommend that where structures are to be constructed, compressible soils should be removed (and replaced with compacted fill as appropriate), compressible soils should be preloaded so that post-construction settlement is reduced, or the structures should be supported on piles or pile-like systems. Alternative piling systems that have been recommended or used in the study area or that may be appropriate include: driven pipe piles, augercast piles, drilled shafts, micropiles, helical piers, and stone columns (e.g., Geopiers™). In our opinion, timber piles could be used to support structures but should not be used for long-term applications where the piles extend above the minimum groundwater elevation. Provisions for differential settlement should be included in designs where differing foundation conditions or types are present below connected structures. Vibrations caused by pile-driving operations could impact existing structures and improvements. We recommend that the potential for vibration-induced damage be evaluated when driven piles are proposed.

Construction of below-grade basements and parking may be proposed at some sites. Excavation to construct below-grade portions of buildings could be performed to partially or completely remove compressible soil from below the structure. Performing this excavation could reduce settlement to tolerable levels or allow the building to be founded on soil less subject to excessive settlement. We recommend that below-grade building elements be sealed to reduce infiltration. Seepage into structures can be reduced by designing foundation elements and walls to limit cracking and by applying geomembranes and bentonite blanket barriers outside below-grade walls. Interior seepage collection and removal and air management systems could be installed and employed to accommodate water that does seep through below-grade structure elements.

Buildings should be designed to resist uplift forces when the groundwater surface elevation is or could rise above base of the building foundations and where water has or could pond above ground surface as a result of elevated groundwater or flooding. Uplift may be resisted by installing tiedown anchors and by increasing building mass, e.g., by thickening concrete foundation and floor slabs. Some pile types may be designed and constructed to resist uplift forces. Appropriate factors of safety that account for uncertainty in groundwater elevation and resisting forces should be applied when designing structures to resist uplift.

A.3 BACKFILL ADJACENT TO STRUCTURES

Sloped excavations are commonly made around the perimeter of work areas to facilitate construction, e.g., outside of and adjacent to basement walls. Backfill of these excavations with common, structural backfill soils could result in (1) compression of soils that underlie the wedge of backfill soil, (2) settlement of the ground surface above the soil wedge, (3) rotation of the soil wedge away from the structure wall, and (4) damage to utilities that pass through the soil wedge.

We recommend that provisions be made to limit or address the effects of settlement around structures that could occur where backfill is placed adjacent to them and where this backfill is supported (in whole or in part) by compressible soils. Vertical shored excavations and incorporation of the shoring elements into the permanent structure are two methods that might be considered.

A.4 GRADING AND PAVED SURFACES

Placing fill to modify grades to facilitate surface drainage or otherwise raise the ground surface, and to construct roadways, driveways, sidewalks, and parking areas could contribute to settlement where these areas are underlain by peat and compressible soil. Paving over existing graded and paved areas underlain by peat and compressible soil could also result in settlement.

For graded and paved areas, we recommend that methods to limit settlement be implemented if the anticipated settlement and maintenance required because of settlement cannot be tolerated. Methods for limiting settlement include removing peat and compressible soils (and replacing with compacted fill if appropriate), preloading so that post-construction settlement potential is reduced, using lightweight fill, and improving the ground. Wood chips and expanded polystyrene (EPS) are possible lightweight mass fill alternatives. EPS suitable for these applications weighs about 1 to 2 pounds per cubic foot. Buoyancy should be considered in designs that incorporate lightweight materials.

One ground improvement alternative that might be applicable to limit fill and paved area settlement would consist of installation of stone columns, e.g., Geopiers™, through compressible soils. The stone columns would likely be installed at about 6- to 10-foot spacing. A two-dimensional geosynthetic (geotextile and geogrid) reinforcement could be placed over the improved ground and fill placed over the geosynthetic.

A.5 UTILITIES

Where utilities are to be installed in or over peat and compressible soils, we recommend that the installations be performed such that the effective load acting on the soils is not increased. Methods for limiting load increase as a result of utility construction include, but are not limited to:

- Limiting excavation widths and depths so that the backfill weight is offset by the weight of soil displaced by the utility. For this case, sloped excavation sidewalls below the base elevation of existing fill materials should be avoided.
- Using lightweight backfills around the utilities. Lightweight utility backfill alternatives include reuse of peat excavated for utility installation and lightweight foam cement. Lightweight foam cement has unit weights in the range of 18 to 60 pounds per cubic foot. Buoyancy should be considered in designs that incorporate lightweight materials.
- Supporting utilities on piles or pile-like systems. Utilities could be directly supported by piles or constructed on pile-supported slabs. Ground beneath piles could also be improved by installing Geopiers™. Pile-supported utilities should not be installed where adjacent ground could settle, because this may result in bumps in the ground surface over the utilities, differential settlement, and utility damage.

Utilities, utility backfill, and utility support systems should be designed so that structural integrity of the completed system is ensured and impacts to adjacent improvements are limited. Provisions should be made to accommodate differential settlement where utilities connect with structures.